Possible Vulnerabilities of Cochin, India, to Climate Change Impacts and Response Strategies to Increase Resilience

June 2003

Oak Ridge National Laboratory
and
Cochin University of Science of Technology

In partnership with the
U.S. Agency for International Development

POSSIBLE VULNERABILITIES OF COCHIN, INDIA, TO CLIMATE CHANGE IMPACTS AND RESPONSE STRATEGIES TO INCREASE RESILIENCE

June 2003

At the U.N. Framework Convention on Climate Change (UNFCCC) Conference of Parties in New Delhi, India, in November 2002, it was resolved that all Parties should "continue to advance the implementation of their commitments" to mitigate climate change but also to focus "urgent attention and action on the part of all countries" to support adaptation to adverse effects of climate change, especially in developing countries.

II

CONTENTS

List of Figures, Maps, and Photographs

VI

BLANK PAGE

FOREWORD AND ACKNOWLEDGEMENTS

This pioneering assessment effort began with participation by Mr. Robert MacLeod of USAID in a summer workshop of the Aspen Global Change Institute in July 1999 on understanding climate change impacts on cities. Co-organized by Thomas J. Wilbanks of the Oak Ridge National Laboratory, that workshop discussed the growing knowledge base about such impacts on cities in industrialized countries, especially in the United States as a result of the first U.S. assessment of possible impacts of climate variability and change; and it noted a lack of equivalent information about possible impacts on cities in developing countries. One reason for this lack, among several, was a perceived shortage of data to support sound assessments, including relatively small-scale regional climate change forecasts for developing countries and relatively detailed data about urban systems and projected changes in those systems.

Rather than accepting that judgment as an insurmountable obstacle, when vulnerabilities to climate change impacts are probably more serious in developing countries than in industrialized countries, this assessment was undertaken as an experiment, with three generic aims:

(1) To learn about potentials and limitations of climate change impact assessments in developing country cities, based on currently available data

(2) To evaluate whether reductions in climate change impact vulnerability can be related to other, more current urban development needs in developing countries

(3) To take a first step toward the development of assessment approaches and tools that can be used by developing countries worldwide to assess their own vulnerabilities and response options

In many ways, thanks to the assistance of a wide variety of individuals and institutions (some of which are listed below), this experiment proved to be more successful than might have been expected. Despite very limited data, it led to the identification of several significant impact concerns in the host city, linked with the area's prospects for sustainable development. It also led to the identification of a number of appropriate responses, at least some of which are likely to be followed up by specific actions in the host city. In addition, it is leading to work on internet-accessible generic assessment approaches that can be used by other cities in India and other developing regions to carry out similar assessments through their own initiatives.

Acknowledging every individual and institution who contributed to this moderate-sized project would require too many pages to be practicable, but certain key roles should be noted. First and foremost, the authors would like to acknowledge the significant contributions to this assessment by Robert MacLeod, urban program officer in the Office of Energy and Information Technology in USAID's Bureau for Economic Growth, Agriculture, and Trade. Bob's support, leadership, enthusiasm, and intellectual partnership were invaluable in making this effort a success. The authors also acknowledge significant contributions by Mr. N. B. Bhattacharjee and Mr. A. Rudra of the urban program in USAID's Mission in New Delhi, as well as financial support from both USAID's Office of Energy and Information Technology and USAID's Climate Change Program.

In Cochin, the project would not have been possible without the active support of Mayor C.M. Dinesh Mani, whose letters of introduction opened doors for the assessment team throughout the Corporation of Cochin. Mr. K. J. Sohan, Former Mayor of Cochin, was instrumental in arranging Cochin's participation as the host city and provided wise advice and council throughout. Mr. Aloysius Mathew, Secretary of the

Corporation of Cochin, was a source of important perspectives on urban processes and stresses in the metropolitan area. Mr. Simon Matthews of the Goshree Islands Development Authority was a friend, a partner, and a source of invaluable information and assistance. Dr. Rajan Chedambath of the Centre for Studies in Culture and Heritage of Cochin assisted the team in its interactions with the Corporation of Cochin. The authors would also like to acknowledge logistical assistance from the Business Centre of the Taj Malabar Hotel.

The assessment was conducted through a partnership between the Cochin University of Science and Technology (CUSAT) and the Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee, USA. At CUSAT, besides the contributions of a strong team from the Centre for Monsoon Studies, Department of Atmospheric Sciences, the project benefited from the interest and support of Dr. N. Unnikrishnan Nair, Vice-Chancellor. At ORNL, the project was ably assisted by Ms. Sherry Wright, Coordinator of Developing Country Programs, Mr. Robert Conrad, Supervisor of Communication Systems, Central Research Library, and Ms. Amy Campbell, Subcontract Administrator, Procurement Division.

Executive Summary

It is now recognized that the global climate is warming and that South Asia is especially vulnerable to impacts of changes in temperature, precipitation patterns, storm behavior, and the sea level. At a national seminar in Hyderabad, India, in December 2000 on climate change and India's cities, sponsored by USAID and attended by high-level representatives of more than 40 major cities, it was agreed that implications for Indian cities should be investigated. At that seminar, Cochin's representative, the Honorable Mr. K. J. Sohan, was asked by USAID if Cochin would be willing to host the first such assessment.

In December 2001, the assessment began, with the approval and support of the Mayor, the Honorable Mr. C. M. Dinesh Mani. It has been conducted through collaboration between the Oak Ridge National Laboratory, USA (ORNL) and the Cochin University of Science and Technology (CUSAT), with support from USAID. The assessment benefited from contributions from a wide range of local officials, especially related to issues for which data were limited.

At the outset, it was agreed by all parties to the assessment that it should lead directly to significant actions that reduce Cochin's vulnerabilities to possible longer-term climate change impacts while also addressing urgent problems for the city's sustainable development in the nearer-term. Consequently, the assessment goes beyond an evaluation of possible impacts to recommendations of actions that should be pursued by the city in partnership with USAID and other organizations.

Global climate change has the potential to be an opportunity for the Cochin area as well as a potential problem. As the first city in the developing world to be the site for an assessment of possible impacts of climate change, this assessment concludes that Cochin can reduce its vulnerabilities to climate change impacts in the long run by taking actions that promote its sustainable urban development in the immediate future as well as by joining in the global effort to reduce the magnitude of eventual climate change.

Although Cochin is likely to be less exposed to climate change impacts than many other Indian cities, such as cities on the east coast of the country subject to sometimes violent seasonal storms, it was invited to be the site for this study because it is considered to be a well-managed city, it is involved in a number of infrastructure improvement projects where investments might be negatively affected by climate change, and it has a reputation as a city that often serves as an innovator in pioneering new issues and responses.

The assessment reflects two underlying philosophies. *First*, impacts of global climate change are likely to focus not on climate changes in isolation but on interactions between climate change and *other* stresses on the city's growth and development, such as water logging or waste disposal. Second, because climate change is a long-term issue surrounded by uncertainties, it is not generally appropriate to take actions now to reduce possible climate change impacts unless those actions also contribute to addressing current urban problems.

Based on available information that is in many cases quite limited, the assessment report summarizes climate change forecasts for the Cochin area, identifies and evaluates impact issues for the area, emphasizing interactions between possible climate changes and existing stresses on urban systems; and considers strategies for reducing impact vulnerabilities that concentrate on reducing stresses on existing systems, therefore making sense for other reasons than climate change alone.

One of the major opportunities lies in the fact that climate change has become a policy concern for countries and lending agencies throughout the world. A principal outcome of the 1992 Rio Conference on Environment and Development was a Framework Convention on Climate Change (UNFCCC), which calls for annual meetings of the signers to the convention, called a Conference of Parties (COP). The eighth such meeting was held in New Delhi, India, in October-November 2002, indicating India's interest in climate change issues. The resulting "Delhi Declaration" stresses the importance of adaptation in developing countries to reduce vulnerabilities to climate change impacts. Because of this interest, urban problem-solving that can be connected with climate change impact vulnerabilities may be able to attract external financial assistance that would otherwise not be available, such as two new UNFCCC funds that provide support for investments that improve a developing country's ability to adapt to impacts of climate change: a Least Developed Countries Fund and a Special Climate Change Fund. In addition, the fact that this assessment is the first of its kind in any developing country city puts Cochin in a position of potential leadership, both regionally and globally.

Climate change is expected to affect human settlements and activities in many parts of the world through four impacts: (1) a gradual increase in the global average temperature; (2) changes in precipitation patterns, in some areas increasing precipitation while in others decreasing precipitation, but in all areas leading to greater seasonal and annual variability in precipitation and to more of the precipitation occurring in a smaller number of intense storm events; (3) an increase in storm intensities, along with changes in storm tracks; and (4) a rise in the sea level.

Impact concerns for Cochin are related mainly to possible changes in precipitation patterns and a rise in the sea level, with impacts more likely to emerge gradually over the next half-century than to have major near-term effects. The most significant vulnerabilities are possible *impacts on Cochin's water systems*, especially drainage, waste disposal, and water logging, of a combination of increased variability and intensity of rainfall and sea level rise and possible *impacts of sea level rise* on land uses at the coastal margin, such as backwater islands under the responsibility of the Goshree Islands Development Authority. Several other types of climate change impacts could also be significant for Cochin, although currently available information is not sufficient to support conclusions about the appropriate level of concern, such as possible impacts of climate change on human health, possible impacts of climate change on the Cochin area's fisheries industry, possible impacts on Cochin's rich and touristically-promising cultural heritage, and possible impacts on Cochin from climate changes in other regions, such as in-migration of environmental refugees from areas affected by drought or sea level rise.

None of these possible impacts is an enormous threat to Cochin's future (barring improbable but possible abrupt changes in the global climate), but a number of actions to reduce current stresses and to improve systems for monitoring environmental change can both help to meet current urban development needs and also strengthen Cochin's ability to handle longer-term challenges. Many of these actions would be relatively expensive, involving substantial investments in capital infrastructure, such as a major canal restoration project. It is not the purpose of this assessment to lay out a full agenda of possible actions, including a comprehensive investment strategy. Instead, the assessment recommends a number of specific first steps toward a more comprehensive response, leaving implementation to further interactions between Cochin and a variety of potential partners, including but not limited to USAID. These steps, we suggest, are likely to lead to further steps that would add up to a truly historic program of action for the Cochin area, making it a model of climate change response combined with contemporary sustainable development.

The recommended actions are as follows:

(1) Take steps to address Cochin's inadequate *waste disposal infrastructure*. It is recommended that, in collaboration with USAID, Cochin upgrade its plans for solid waste disposal. To assist in this effort, USAID has supplied technical assistance to help Cochin meet Indian Supreme Court requirements for solid waste disposal planning.

(2) Identify funding sources and develop a proposal for funding of a *canal restoration* initiative. It is recommended that Cochin explore funding potentials for a major canal restoration effort that might begin with a formal proposal for donor assistance for a prototype project. USAID will be assisting Cochin in scoping such a project.

(3) Take steps to link urban problem-solving with *climate change mitigation* as well as adaptation, where local co-benefits exist. As a first step in linking Cochin with other developing country cities concerned about climate change issues, it is recommended that Cochin join the Cities for Climate Protection program funded and supported by USAID and administered by the Toronto-based International Council for Local Environmental Initiatives (ICLEI)—an international network of more than 300 cities—to implement a program of cost-saving energy efficiency improvements, probably emphasizing municipal facilities, vehicle fleets, and street lighting.

(4) Enhance Cochin's *leadership position* in environmentally sustainable urban management. It is recommended that Cochin provide leadership in the formation of a proposed Kerala State Council of Mayors and Kerala State City Manager's Association and that Cochin be invited to participate in national, regional, and global conferences and forums related to urban management and also issues associated with climate change. It is also recommended that Cochin use its participation in the ICLEI network of cities to communicate its experiences and accomplishments.

(5) Continue with efforts to strengthen linkages between the Corporation of Cochin and CUSAT for *technical assistance* in increasing the resilience of the Cochin area to climate change impacts and contributing in other ways to effective urban management and problem-solving and for local *capacity-building*. As a consequence of the assessment, CUSAT and ORNL are developing a Memorandum of Understanding for continuing technical collaboration, including such subject areas as climate change modeling and monitoring.

(6) Develop and implement an action plan to *improve information* to inform decision-making and project development, emphasizing certain high-priority needs and certain types of impact concerns that could emerge as significant as they come to be understood better.

GLOSSARY

Cochin. The traditional name of Kerala's principal port city, the site of the assessment (see Kochi).

Cochin Port Trust. An authority which operates Cochin's commercial waterways and port facilities.

COP. Conference of Parties, a periodic (normally annual) meeting of the parties to UNFCCC (see below).

Corporation of Cochin. The central city of Cochin.

CSCHC. The Centre for Studies in Culture and Heritage of Cochin, an initiative of the Corporation of Cochin.

CUSAT. The Cochin University of Science and Technology.

EIA. Environmental Impact Assessment.

Ernakulam District. The District of the Indian State of Kerala of which Cochin is a part.

GCM. General circulation model also used to refer to global climate models.

GHG. Greenhouse gases, the gases that cause a greenhouse effect in the earth's atmosphere.

Goshree Islands Development Authority (GIDA). A governmental authority that coordinates development in a large coastal area including a portion of the Cochin metropolitan area.

Greater Cochin Development Authority (GCDA). A governmental authority that coordinates development in the Cochin metropolitan area.

ICLEI. The International Council for Local Environmental Initiatives, which administers the international Cities for Climate Protection program.

IIT. Indian Institutes of Technology, with campuses in a number of major Indian cities.

IPCC. The Intergovernmental Panel on Climate Change, which produces periodic multi-volume assessment reports that summarize the current knowledge base about climate change issues.

Kerala. An Indian state at the southern end of the country's west coast.

Kochi. The modern name of Cochin (see Cochin).

Monsoonal. Related to large atmospheric circulation systems that are responsible for most of India's seasonal rainfall.

ORNL. Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA—managed by UT-Battelle LLC for the U.S. Department of Energy

RCM. Regional climate model.

Sustainable. Capable of being sustained indefinitely, as in sustainable development (which includes both economic and environmental sustainability).

UNFCCC. The United Nations Framework Convention on Climate Change.

USAID. U.S. Agency for International Development.

Vulnerability. Generally, susceptibility to threat, including exposure to the threat, sensitivity to the threat, and coping capacity. Can also include the idea that what is a threat to one party can be an opportunity to another, such as more or less rainfall or increased biomass production due to increased presence of carbon dioxide.

POSSIBLE VULNERABILITIES OF COCHIN, INDIA TO CLIMATE CHANGE IMPACTS AND RESPONSE STRATEGIES TO INCREASE RESILIENCE

INTRODUCTION

It is now recognized that the global climate is warming and that South Asia is especially vulnerable to impacts of changes in temperature, precipitation patterns, storm behavior, and the sea level. At a national seminar in Hyderabad, India, in December 2000 on climate change and India's cities, sponsored by the U.S. Agency for International Development (USAID) and attended by high-level representatives of more than 40 major cities, it was agreed that implications for Indian cities should be investigated. At that seminar, Cochin's representative, the Honorable Mr. K. J. Sohan, was asked by USAID if Cochin would be willing to host the first such assessment.

In December 2001, the assessment began, with the approval and support of the Mayor, the Honorable Mr. C. M. Dinesh Mani. It has been conducted through collaboration between the Oak Ridge National Laboratory, USA (ORNL) and the Cochin University of Science and Technology (CUSAT), with support from USAID. The assessment benefited from contributions from a wide range of local officials, especially related to issues for which data were limited.

This preliminary assessment of the possible impacts of global climate change considered the coastal environment of the central city (the Corporation of Cochin) and metropolitan area of Cochin (officially renamed Kochi). Cochin is a city of about 600,000 people within a metropolitan area of about two million, located in the state of Kerala on the southwest coast of India (see Map 1). A major port since the 12th century, Cochin consists of numerous islands and parts of the mainland linked by water transport and bridges.

Map 1. The location of Cochin.

Based on very limited available data, along with discussions with local authorities and experts, the assessment summarizes climate change forecasts for the Cochin area; identifies and evaluates impact issues for the area, emphasizing interactions between possible climate changes and existing stresses on urban systems; and considers strategies for reducing impact vulnerabilities that concentrate on reducing stresses on existing systems. Section 1 of the report sketches the background of concerns about possible impacts of climate change in urban coastal areas, along with the objectives of the assessment and the methodology utilized. Section 2 describes Cochin and its surrounding area in order to provide a context for the assessment. In Section 3, available data and information related to trends and projected changes in temperature, precipitation, and sea level for the Cochin area are presented and discussed. Section 4 briefly summarizes how projected changes can be related to impact concerns, and Section 5 examines implications of possible climate changes for Cochin. Section 6 presents conclusions about potential climate change impacts on the Cochin area, and Section 7 recommends actions that can be taken to reduce vulnerabilities to impacts of climate change within the Cochin area while enhancing continued urban development and improvements in the quality of life.

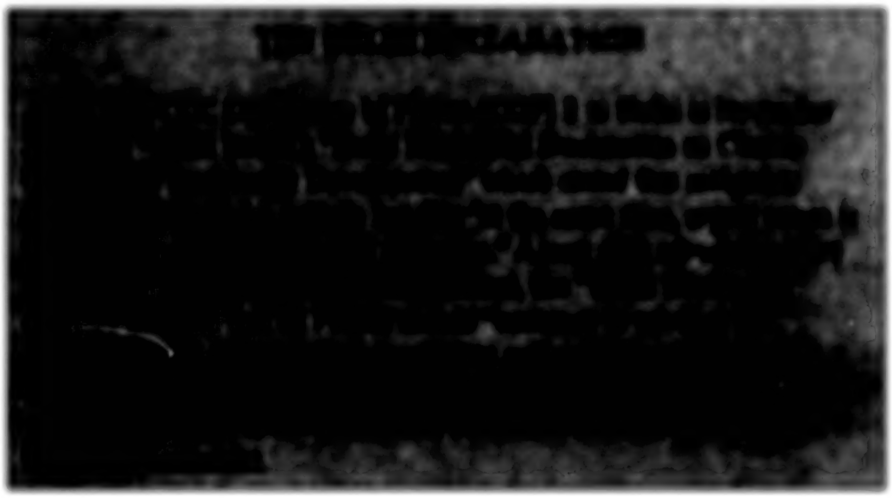
Background

Climate change is a recognized concern for countries throughout the world, both industrialized and developing. One of the principal outcomes of the 1992 Rio Conference on Environment and Development was a Framework Convention on Climate Change (UNFCCC), which calls for annual meetings of the signees to the convention, called a Conference of Parties (COP). The eighth such meeting was held in New Delhi, India, in October–November 2002, indicating India's interest in climate change issues. The "Delhi Declaration" resulting from that meeting (see box) emphasized the growing importance of vulnerabilities of developing countries to impacts of climate change and the need for assistance with adaptation in order to reduce those vulnerabilities.

The effects of climate change on the Earth's environment will be manifested most directly through four mechanisms. First, although some anomalies are to be expected, most climate experts agree that human-induced climate change will increase average global atmospheric and sea surface temperatures. Second, temperature increases will be associated with changes in precipitation patterns worldwide. Third, changes in storm tracks and intensities are likely to occur. Fourth, the sea level is expected to rise due to a combination of thermal expansion and the melting of mountain glaciers and the polar ice caps. Although most climate change forecasting models imply relatively gradual changes in these regards, it is widely agreed that climate change is likely to be accompanied by increased climate variability and by an increased risk of extreme events and surprises (e.g., OTA, 1993).

The Intergovernmental Panel on Climate Change (IPCC 2001a) has estimated that globally averaged surface temperatures may increase by 1.4–5.8°C in 2100 relative to 1990. Along with the increase in average temperatures, models also project that the globally averaged sea level will rise 0.2–0.9 m by 2100. The lower forecasts assume a significant global effort to reduce greenhouse gas (GHG) emissions that now seems unlikely; therefore, it is prudent to consider possible impacts of the upper ranges of forecasted changes. Meanwhile, climate changes and their impacts are already being observed on every continent of the earth, especially in snow and ice cover and in polar region ecologies. Climate change impacts, therefore, are no longer hypothetical (IPCC 2001b).

An understanding of dimensions of the vulnerability of places to impacts of climate change is still emerging, but one widely used formulation identifies three dimensions: exposure to climate change stresses, sensitivity to those stresses, and coping capacity for dealing with the stresses (Clark et al., 2000). According to the Third Assessment Report of Working Group II (Impacts, Adaptation, and Vulnerability) of the IPCC (IPCC, 2001, Chapter 7), the factors most likely to affect the impacts of climate change on human settlements are location (coastal or riverine areas more *exposed*), resource dependence of the economy (e.g., settlements dependent on climate-associated sectors such as agriculture or forestry more *sensitive*), and wealth (a crude indicator of *coping capacity*).



Coastal areas are particularly vulnerable to climate change impacts, because they are especially affected by sea level rise and monsoonal storms and because they are often relatively densely populated. Low-lying cities on gently sloping seacoasts are generally more vulnerable, with such cities in developing countries the most vulnerable, although a host of other factors—locational, economic, ecological, and institutional—can moderate these vulnerabilities.

These issues have been of co...cern to a number of research centers and other parties in India. For instance, the Tata Energy Resear..ch Institute (TERI) of New Delhi pioneered the first Internet site offering information about climate chan..ge issues in Asia. The Indian Institute of Technology (IIT) - Delhi collaborates with the Hadley C..entre in the UK in climate change forecasting and has produced regional climate forecasts for India (see Section 3); and it is engaged in research on such climate change issues as implications for India's food security. The Indian Institute of Tropical Meteorology (IITM), an arm of the Indian Meteorological Department located in Pune, is also developing regional climate change scenarios. Meanwhile, TERI continues to conduct climate change related studies, with its Director, Dr. R. K. Pachauri serving as the new head of the Intergovernmental Panel on Climate Change (IPCC); such experts as Dr. Anand Patwardhan at the Mehta School of Management at IIT-Bombay are active in research and policy discussions about adaptation potentials; and Dr. Jyoti Parikh and her colleagues at the Indira Gandhi Institute for Development Research in Mumbai (Bombay) are closely associated with IPCC scenario development and modeling activities.

This level of professional activity and international leadership has re..cently been matched by interests in climate change policy as well, as indicated by India's hosting of the UNFCCC COP-8 meeting and its active participation in formulating the Delhi Declaration.

PURPOSE

The purpose of this report is to present results from the first detailed assessment of potential impacts of climate change on a city in a developing country, in essence bringing global and large-regional issues down to relevance at a local scale. Besides providing information and recommendations for actions that should assist Cochin in reducing its climate change impact vulnerabilities, the assessment is also intended to provide a model for other cities worldwide, giving the Cochin assessment global significance and placing Cochin in a place of leadership in the global community.

This assessment is intended to: consider the likelihood that Cochin will be exposed to climate change impacts; consider the sensitivity of Cochin to various kinds of impacts; assess Cochin's coping capacity and how it might be enhanced, with special attention to strategies that also support other urban management priorities; and lead to a response strategy for Cochin, including the identification of practical implementation steps.

While the assessment is expected to contribute to general understandings about adaptive responses to climate change impact vulnerabilities in developing countries worldwide, its main objective is to catalyze tangible actions to enhance Cochin's urban development and management, targeted on ways that Cochin's vulnerabilities to climate change are rooted in more deeply-seated stresses within the urban area. Benefits are expected to include contributions to a more integrated approach to urban environmental planning and management; improved information about technical and institutional options; assistance in harnessing investment for projects that contribute to Cochin's development in the near future while increasing its resilience to possible climate change impacts in the long term; major advances in Cochin's position as a global leader among developing country cities in considering responses to climate change concerns; and identification of needs for improved information to enhance urban planning and decision-making in the future.

METHODOLOGY

The assessment began with a scoping and coordination phase in December 2001. Delayed by a period in early 2002 during which USAID assistance activities were suspended in India, it continued with activities by CUSAT during the spring and summer of 2002 and collaborations with ORNL in September, October, and early November, including interactions with a wide range of local officials and experts in both the Cochin area and throughout Kerala. On November 6, 2002, preliminary findings were discussed with representatives of the Cochin City Council and other distinguished political leaders; and a draft assessment report was circulated to 55 interested parties for their comments (see Appendix A: Participants in the Study). In January and early February 2003, the CUSAT-ORNL team (Photo 1) collected comments and added information and data wherever possible as contributions to the final report. This process included a workshop with ten local experts and a public hearing, publicized in local newspapers and widely reported in newspapers and local television outlets. On February 4, 2003, Mr. Robert MacLeod of USAID, the program manager, and the team discussed recommendations for action with the Mayor and representatives of the City Council and the political parties; and agreement was reached on a number of steps to be taken, with other implementation discussions to follow.

The assessment was based on methods for environmental impact assessment (EIA) that have been developed over a 30-year period in connection with the National Environmental Policy Act (NEPA) in the

Photo 1. CUSAT-ORNL team.

United States (for a review, see Hildebrand and Cannon, 1992). This approach combines a variety of well-tested approaches for gathering and analyzing quantitative and qualitative information about the phenomenon, action, or facility of interest and impacts that could result, along with strategies for reducing those impacts and involving local interested parties in both scoping an assessment and reviewing preliminary results. Shaped by experience in the relatively data-rich context in the United States, the U.S. EIA approach requires some flexibility and sensitivity when applied in a data-limited developing country context (Wilbanks et al, 1992), especially for a newly-emerging issue such as climate change. On the other hand, it offers a tested and documented starting point that has been applied successfully in USAID-supported projects in developing countries (e.g., CONAMA, 2000), especially when it can be combined with knowledge bases especially relevant to the contexts of those projects (e.g., Ensminger, 2003).

The Cochin Context

As mentioned above, at a national conference on climate change and urban development in Hyderabad, December 2000, sponsored by the U.S. Agency for International Development (USAID), the attendees agreed that it would be highly useful to conduct a prototype assessment of climate change impacts on an Indian city. Cochin was invited to be the partner in this prototype city because it is considered to be a well-managed city, it is involved in a number of significant infrastructure improvement projects where investments might be negatively affected by climate change, and it has a reputation as a city that often serves as an innovator in pioneering new issues and responses.

If a person were to select an Indian city relatively unlikely to be negatively impacted by global climate change, that city might be Cochin. For instance, the immediate proximity of Cochin to the ocean would be expected to moderate temperature increases, and its west coast location—sheltered by the Western Ghat mountain range—protects it from impacts of damaging monsoonal storms that plague India's east coast. Moreover, Cochin is recognized as a well-managed city, located in a state with a high level of social services; and its adaptive capacities would be expected to be unusually high. As a result, if an assessment were to identify significant impact concerns in Cochin, one implication would be that many other Indian cities may have more serious possible impacts to consider.

In carrying out an impact assessment of a city, an assessment of long-term (e.g., 50-year) impacts of climate change would ideally be associated with forecasts of economic, demographic, and social change over that same period. Such forecasts are unavailable for Cochin (as for most of the world's other cities), and a wide variety of other types of contextual information for the city are also unavailable. Improving information about economic, environmental, and other conditions and trends would be of significant value to the city as it contemplates its complex future. Lacking these kinds of data, however, it is still possible to set the scene by characterizing Cochin as a metropolitan area.

The Environmental Setting

Cochin is a charming coastal city in the Indian state of Kerala which consists of a number of low-lying islands, peninsulas, and other parts of the mainland linked by water bodies, including a major international harbor, rivers, and canals. The average elevation of the city is about 1.5 meters. Toward the interior are more "backwaters," in many cases relatively clean and unspoiled and a lure for tourism but increasingly impacted by urban development. Farther inland, the land surface rises to the Western Ghat mountain range, which defines the border of Kerala. Exports of spices, nuts, and other products such as rubber in hill plantations were a basis for Cochin's growth as a port, along with exports of fibers and other useful products from coconut farming.

The area is warm and humid, with two monsoon periods annually, neither as intense as the major summer monsoon on India's east coast and neither associated historically with disastrous flooding or other storm damage. A Southwest Monsoon, which brings the heaviest rains to the area, occurs in the June–August period, and a Northeast Monsoon occurs in the September–December period. Total precipitation is about 3000 mm annually, about two-thirds of that from the Southwest Monsoon.

At the Northern end of the Cochin coastline, the Periyar River opens to the Arabian Sea, one of six rivers discharging into Cochin's backwaters. Midway in the metropolitan area lies the entrance channel to

Cochin Harbor, which is dredged continuously. About 10 million cubic meters of sediment are dredged annually from Cochin port area and dumped offshore or deposited as landfill for shoreline developments. The tidal flux in Cochin's coastal waters is about one meter, with tidal flows complicated by a complex topography.

Population

According to the census of 2001 (provisional), the total population of Cochin corporation is 596,473, which represents a very small rate of growth over the preceding ten years. The population of the metropolitan area (the area included within the Greater Cochin Development Authority: GCDA), was 1,652,871 in 1991 (Map 2). Official 2001 figures are not yet available, but they are estimated to be about 2 million, a faster rate of population growth than for the central city (and faster than the state's relatively slow-growth ten-year average growth of 12%). Within the GCDA area, an additional 300-400,000 "floating" individuals commute daily into Cochin from outlying areas for employment. The population of the larger Ernakulam District was about 3.1 million in 2001, about ten percent of the total population of the state of Kerala. Of the total population of Cochin, 8.5% are above 60 years of age, 7.5% 50-60, 27% 30-50, 22% 20-30, 27% 5-20, and 8% below 5 years of age.

Human resource indicators such as education levels and literacy are unusually high throughout Kerala; the literacy rate is reported to be virtually 100%. 40 schools, 5 colleges, a regional study centre of the Mahatma Gandhi University, and the Law College and Marine Campus of the Cochin University of Science and Technology are located in the central city area.

The social context of Cochin is complex, including significant Hindu, Christian, and Muslim populations, plus an influx of Tamil workers from Tamil Nadu who fill low-wage economic niches. The city's long history of international trade makes it unusually cosmopolitan, with many linkages of family and friendship with individuals living and working in the Gulf States, Europe, and North America.

Organization and Governance

The city of Cochin is democratically governed by the Corporation of Cochin, which includes 66 divisions. The elected council members of the divisions form a governing body headed by the Mayor, who is elected by this body. The Corporation has standing committees for finance, development, welfare, health and education, public works, tourism planning and heritage, and taxation; and it maintains five zonal offices at Edappally, Fort Cochin, Mattancherry, Palluruthy and Vytilla. The Corporation is responsible for local governmental activities including waste management, drainage and canal systems, sewage treatment, health, birth and death registration, and part of education.

Development in the larger metropolitan area is coordinated by the Greater Cochin Development Authority (GCDA). This larger area includes the city of Cochin, 10 municipalities, 15 blocks, and 6 other local governmental units. Also within the metropolitan area are the Cochin Port Trust, which operates the area's commercial waterways and port facilities; the Goshree Islands Development Authority, which is responsible for development planning for 27 islands northwest of the city of Cochin, including the development a major capital improvement project calling for the construction of three bridges and a world-class container shipping terminal; the headquarters of the Indian Navy in South India; and other institutions and authorities.

Map 2. The Cochin area.

A number of governmental functions important to urban area management are the responsibility of the state of Kerala rather than the city. Important examples include electric power supply, potable water supply, law and order, traffic, some aspects of taxation, agriculture, fisheries, and environmental protection and forest management. The state's Department of Town Planning maintains a Regional Town Planning Office in Ernakulam which is concerned with land-use planning and other development issues in the metropolitan area.

A planning process is currently underway to develop a vision for the future development of the city of Cochin. A draft document has been prepared which describes the current status and future plans for two key aspects of development—transportation and land use—within the city. According to local authorities, the climate change impact assessment for Cochin has served as one focus for integrating this process and promoting awareness of the planning processes for these and other key Cochin operations.

Key issues identified in the current planning process related to potential climate change impacts are solid and sanitary wastes, drainage, inland waterways, and land use. The vision for waterways includes full utilization of backwaters and canals for transportation, including reclamation and widening of some canals and improvement of boat jetties for use as terminals. Land-use plans include establishment of industrial clusters (emphasizing light industry such as information technology applications), promotion of developments that encourage tourism, and improvement of public participation at the neighborhood, zonal, and city levels.

Economic Growth and Land Use

The economy of Cochin, the commercial capital of Kerala, is focused on one of the best natural harbors in the world. The economy of the region emphasizes trade, including major exports of fish, coconut-derived fibers, prawns, tea, cashew kernels, and rubber. In addition, although the state of Kerala is not one of the more industrialized in India, the Cochin area is the site of the state's largest concentration of industrial activity, mostly located in the Cochin Special Economic Zone upriver to the north. This zone includes 55 facilities producing food and agricultural products, chemicals, textiles, ceramics, latex products, wood processing, electronic hardware and software, biotechnology, and engineering.

Extensive employment data are available at the District level, but the Cochin metropolitan area represents less than one-tenth of the population of a considerably agricultural district, reducing the value of these data for understanding the city. Employment appears to emphasize trade, commerce, and government, with the largest employers being the Cochin Port Trust and the shipyards. Unemployment figures are not available, but the influx of labor from Tamil Nadu suggests that unemployment is low in low-wage job categories, while the continuing outflow of more skilled labor to other parts of the world suggests that job opportunities are rather scarce for the higher-wage, higher-skilled job categories.

The per capita income of Cochin is approximately 25000 rupees/year (roughly $500 per year), which is above the state average. Remittances from non-resident Indians from the Cochin area are not documented, but they are believed to be considerable, especially in the form of investments in real estate and other consumer goods upon return to Kerala. Contributions of various categories of economic activity, such as shipping and tourism, to the income pool of the city are not available.

Land use in Cochin is diversified. According to GCDA estimates, 78% of the land area of the Cochin Corporation is residential, followed by 9% for transport and communication, 3% for commercial establishments, 3% for industry, 6% for public and semi-public institutions, and 1% for open space. Most

observers would estimate commercial land use to be greater than this, especially when the intermingling of residential and commercial land uses is considered.

The city of Cochin faces many of the same challenges as other cities in developing countries, although its moderate size and rate of growth—combined with progressive management, high levels of human resources, and the fact that Kerala's strong labor movement has tended to discourage heavy industrial development—have preserved much of its character as one of India's most attractive cities. As examples of challenges, its population of landless poor is increasing, although it does not have the sorts of extensive slum areas characteristic of many other developing country cities, and its traffic is beginning to pose serious challenges, especially in the main commercial center of Ernakulam. Ambitious ideas for progress are being discussed, including a proposed above-ground metro ("Sky Bus").

HUMAN HEALTH

Health care facilities and health indicators in Kerala are among the most impressive in developing countries worldwide. Health care includes both public and private hospitals and providers, general and specialized, and a variety of localized health care centers. Life expectancies are 70 years for men and 65 years for women, unusually high for a developing country. One rising health concern is with increases in air pollution and associated increases in respiratory diseases, mostly in areas downwind from the area's industrial facilities but also due to occasional urban smog to which the growing density of motorized highway vehicles is an obvious contributor.

INFRASTRUCTURE

As in most cities, the physical infrastructures of Cochin—transportation, sanitation, water, and electricity—struggle with complications from urban growth, technological change, and jurisdictional boundaries. For instance, one of the most problematic areas is potable water supply, which is a very serious city concern but a state responsibility that has not kept pace with growing demand. Electricity is also a state responsibility. Until 1996, virtually all electric power was generated from hydroelectric facilities, but hydroelectric power now supplies only about 55% of Kerala's electricity as thermal power projects (from which electricity is more expensive) have been added. Among municipal responsibilities, infrastructures are particularly inadequate for handling solid and liquid wastes, and environmental pollution is endemic as a result. One historic system for water supply, waste disposal, and transportation is the city's extensive network of canals, now largely polluted and encroached upon by urban development. This deterioration of a key historic foundation for the city's infrastructures, combined with the city's situation in a flat, low-lying coastal area, contributes to the city's problems with drainage and water logging.

12

BLANK PAGE

Possible Climate Changes for Cochin

The potential for climate changes in the Cochin area in coming decades can be estimated from available information about projected global and regional climate changes, along with information about Cochin's own climate history.

Temperature Changes

Over the past 50 years, Cochin has experienced an increase in its mean annual temperature of the order of 1°C (CUSAT, work in progress). If this rate of increase were to continue for the next 50 years, the mean annual temperature would be another 1°C warmer than the present. Moreover, the proximity of the city to the sea causes the city's climate to be affected by the sea surface temperatures (SST). An analysis of long-term time series (1856-2000) of SST anomalies off the Cochin coast shows an increasing temperature over the decades except for negative anomaly periods in the 1950-59 and 1970-79 decades. In the case of SST, if the present rate of increase continues the sea-surface off the Cochin coast will be warmer by another 0.3°C by the end of 2050. A small increase in SST is likely to affect the local climate more than the impact of air temperature.

Meanwhile, forecasts of global climate change (IPCC 2001a) show expectations of an increase in global average surface temperatures of 1.4-5.8°C by 2100, with median projections in the range of an increase in the range of 3°C. Locations nearer the equator and nearer oceans are expected to have temperature increases less than the global average, which suggests that effects of this global change on Cochin would be below the average. If, however, an increase of 1 to 2°C as a result of climate change is added to rising temperature trends detected in the absence of climate change, Cochin could be warmer in 2050 than at present by several degrees Centigrade. This expectation is in line with forecasts from other sources of temperature changes in Kerala from climate change (e.g., Lal, 2002).

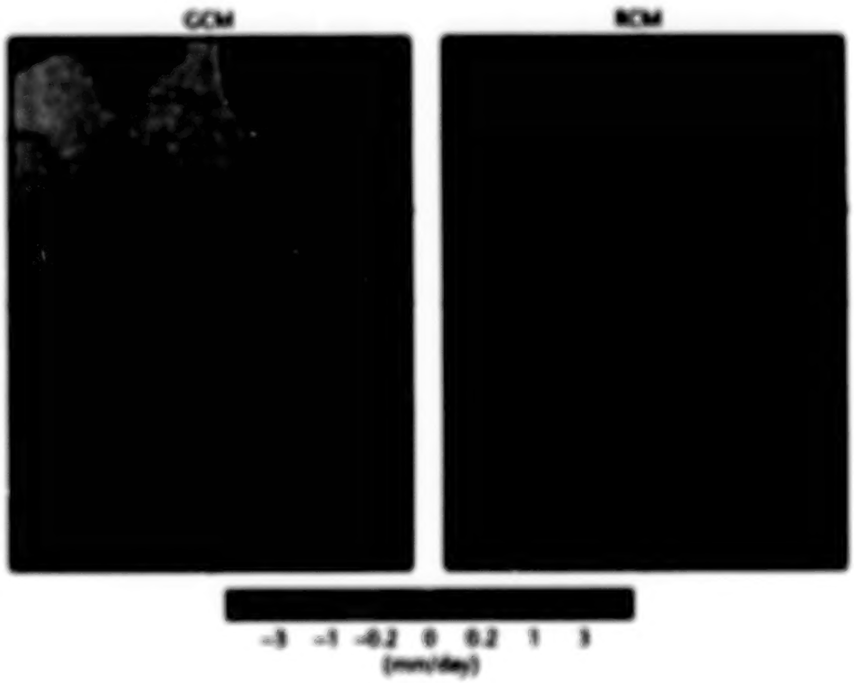
Rainfall Changes

One of the most significant effects of global climate change is expected to be changes in precipitation patterns. For Cochin, long-term trends in total annual rainfall show a very slight decreasing trend of 8 mm/year, although total monsoon rainfall does not show a decreasing trend. More importantly, the average annual number of rainy days in Cochin is 160 days, but over the past 56 years there has been a considerable decrease in the number of rainy days as a part of the annual rainfall pattern (CUSAT, work in progress). It can be inferred that Cochin is receiving more short spells of intense rainfall during the southwest monsoon season and throughout the year than in the past.

Predicting changes in rainfall and its variability in the future as a result of global climate change is more complex. No regional models or modeling capabilities exist at the present for developing specific scenarios for Kerala or Cochin. Atmospheric general circulation models (GCMs) have been used to construct scenarios for Asia and for South Asia; and the Hadley Centre, UK, in association with the Indian Institute of Technology (IIT), Delhi, has developed a first set of estimates of regional climate change within India using a regional climate model (RCM). Different models give somewhat different results regarding patterns of total annual rainfall increase or decrease. For example, some GCMs show a decrease

in annual rainfall in the Kerala region, but predictions of rainfall changes from the Hadley/IIT regional model show a significant increase in total annual rainfall by 2050 (Figures 1 and 2). Most models agree, however, that annual and seasonal rainfall will become more variable and that, in most years, a larger percentage of the rainfall will fall in a smaller number of more intense events.

In summary, rainfall in the Cochin area due to global climate change may increase or decrease, but on the basis of very preliminary modeling it appears that a net increase is more likely. In either case, global climate change is expected to reinforce current trends toward increased variability and intensity in rainfall. For instance, it is expected that more of the area's rainfall will occur in a smaller number of more intense storm events.



Predicted changes in monsoon rainfall (mm/day) over India, between the present day and the middle of the 21st century from the GCM (left) and from the RCM (right). (Hadley Centre, 2000)

Figure 1. Regional climate change forecasts for India (GCM).

Figure 2. Regional climate change forecasts for India (RCM).

Sea Level Rise

Although some local informants indicate that sea level at high tide is rising in the Cochin area, studies of the pattern of sea level over the period 1949 to 1998 (Dinesh Kumar, 2001) do not show a significant rise. The more serious issue is global projections of climate change which indicate that the globally averaged sea level will rise significantly by 2100, perhaps as much as 0.9 meters. Apparent sea-level rise can also be affected by coastal land subsidence or uplifting.

Considering results of global and regional analyses, the likelihood of sea-level rise in the Cochin area in coming decades is very high. Rates of change and the eventual stabilization level are difficult to estimate, but it appears quite possible that sea level in the Cochin area will rise by as much as one-third meter by 2050. In addition, unpublished geological studies indicate some coastal land subsidence in the Cochin area in the past half-century, which could cause the apparent sea level rise to be one-half meter or more.

Storm Behavior

It is not expected that monsoonal storm behavior in the area of the subcontinent will change in ways that would affect Cochin's climate significantly (e.g., regarding hazards from severe weather events), apart from precipitation amounts and intensities.

Summary

In summary, the major effects of climate change on the Cochin area appear to be (a) a likely intensification of precipitation, probably associated with an increased variability in seasonal precipitation and a net average increase in total precipitation and (b) a very high probability of gradual sea-level rise, which—especially if combined with coastal land subsidence—could be as high as one-third to one-half meter in 50 years. Temperatures are also likely to rise, which—combined with increased rainfall—could increase humidity levels at some times of the year. The incidence of severe storms does not seem likely to increase, although more intense periods of rainfall could imply a greater risk of flooding.

Implications of Possible Climate Changes for Cochin

Based on the limited information currently available about likely climate changes, the most serious types of impact concerns appear to relate to precipitation amount and intensity and sea-level rise, although other possible impacts deserve attention as well, such as temperature changes, local ecological changes, and implications of climate changes in other regions. These implications, drawn from the global climate change impact assessment literature, help to focus the impact assessment process by indicating priority issues for attention.

Implications of Precipitation Changes

If rainfall in the Cochin area becomes more variable, with more of the rain falling in relatively short, intense storm events, these changes could have a significant impact on the city's water systems, especially drainage and waste disposal. More intense rainfall means that more of the rain runs off on the surface rather than infiltrating into the ground, an effect that is increased as more of the land surface becomes paved, which can increase flooding and erosion.

While projections of rainfall amounts remain uncertain, either an increase or a decrease could have impacts on the Cochin area. An increase would be associated with more flooding and more rapid siltation of waterways. A decrease would be associated with a greater likelihood of shortages of drinking water, increased water pollution due to less dilution and flushing, more extensive saltwater intrusion, and possibly increased costs of electricity if hydropower potentials are affected.

Implications of Sea-Level Rise

Sea level rise would increase chances of coastal flooding, which might affect some areas of tourism interest. It would increase saltwater intrusion in both surface waters and ground water sources. It would increase the extent of water logging in the Cochin area, especially if combined with increased flooding from intense storm events, and could effect some building foundations. These effects could be important in both the city of Cochin and in the larger Cochin metropolitan area, especially in some of the low-lying islands within the jurisdiction of the Goshree Islands Development Authority.

Implications of Temperature Changes

The most direct impacts of temperature changes would be on demands for water and electric power. Higher temperatures mean increased rates of water evaporation and demands for potable water. They also mean higher demands for electricity for cooling, refrigeration, and fans, especially as standards of living in households and workplaces rise in coming decades.

Implications of Combined Temperature and Precipitation Change

Combinations of changes in temperature and precipitation patterns have the potential to change local human and natural ecologies through changes in humidity and other interactions. One example is possible impacts on human health: changes in pests and pathogens to which people are exposed, changes in the

levels of exposure, and associated public health requirements. Another example is possible impacts on animals and plants in both agricultural and urban areas. Less obvious but extremely important are possible impacts on cultural heritage preservation: historic structures, traditional patterns of activity, and landscapes that are an intrinsic part of what make Cochin and its area so special.

Another area of concern is possible effects on fish populations and species of changes in sea temperatures, chemistry, and/or currents as a result of global climate change. If the fish and shellfish populations on which the Cochin fishing industry relies were to shift in location or shrink in size, which would have a negative impact on an important part of the economy.

Implications of Climate Changes in Other Regions

Finally, possible impacts of climate change on the Cochin area are not limited to what happens within Cochin itself. For instance, sources of inputs to the Cochin economy (such as agricultural products) could be affected if the climate changes in source areas. Cochin's competitiveness in regional and international export markets could be affected (negatively or positively) if the climate changes in competing regions. And some possible regional climate changes in India, especially the possibility of precipitation decreases and more frequent droughts in the interior of southern India, could lead to in-migration of environmental refugees to Kerala.

Assessment of Climate Change Impacts

This section summarizes assessments of possible impacts of climate change on key aspects of the Cochin area, in many cases based on very limited available data combined with judgments of local experts and observations by the assessment team. The assessment summaries generally begin with a review of current stresses on city systems and processes and then consider what the implications of forecasted climate changes for these stresses might be.

Water Systems

As described in Sections 1 and 2, Cochin consists of islands and parts of the mainland linked by water transport and bridges. Within Cochin almost every activity is affected by the waters around and within the city. The ability to effectively manage the quantity and quality of water flowing through and being used within the city is therefore of utmost importance to the quality of life. Key issues include drainage, water logging, flooding, and potable water, with the city's extensive canal system central to many current problems and potential solutions.

Cochin's canals range from wide waterways that once carried water transport and trade to relatively small drainage channels. Major canals include the Thevara-Perumanoor, Rameswaram, Edappally Thodu, and boundary canals. Currently, however, the canals are silted, polluted by solid wastes, seasonally clogged by water hyacinths, and in some cases (such as the Mullasseri Canal from Embassy Road west to Market Road) narrowed by encroachments to increase space for buildings and roadways (Enteem, 2002). Cochin's canals also receive approximately 30% of the city's liquid wastes, adding to problems of pollution, odor, and exposure of the population to disease (see Photos 2 and 3).

Sea-level rise associated with climate change can be expected to raise the groundwater table within the city area and also to raise tide levels. These factors, in combination with more variable but generally more intense precipitation events, could exacerbate the poor drainage and pollution problems of the canals. In addition, the underlying causes of canal pollution and deterioration, including population and economic growth in the absence of effective infrastructures to meet such needs as waste disposal, can be expected to put even more pressure on the canal system as climate change effects are emerging.

Drainage, Water Logging, and Flooding

Cochin is currently experiencing drainage problems during the monsoons resulting from uncontrolled development combined with insufficient drainage infrastructure, although only fragmentary and often qualitative data are available about the frequency and extent of problems such as flooding and water logging. Water flows through the city from two principal sources: (1) the tides regularly force seawater into the canals and backwaters; and (2) monsoon rainfall on the city and eastward in the Western Ghats brings fresh water runoff through the numerous rivers and streams toward the coast. The topography and elevation of the land, the constructed roads, drains, and canal networks; the flow of the tides; and the quantity and duration of precipitation events exert strong influences on the water drainage of the city (Enteem, 2002).

Photo 2. Cochin Canals I: This young man appears happy, but the canal behind him can be smelled from three blocks away and are breeding grounds for mosquitoes.

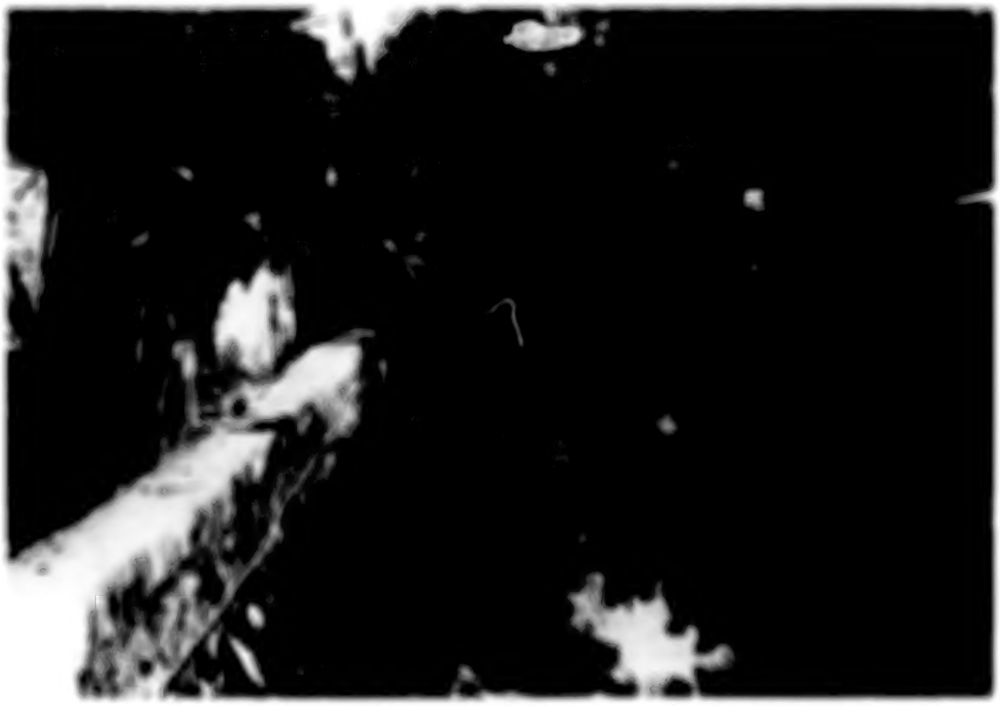


Photo 3. Cochin Canals II: Many of the smaller canals have been constricted by encroachments, and very little water flow occurs (except during floods).

Projections of climate change for the Cochin area indicate increased variability in rainfall and increased intensity in the precipitation that falls, with some likelihood that total precipitation will increase. If precipitation continues the current trend of occurring in shorter, more intense events, then increased runoff, flooding, and water logging can be expected, and water logging could be exacerbated by sea-level rise. In the absence of improvements in drainage infrastructures, these changes could affect the habitability of areas of the city that are already subject to water logging and flooding, which can cause structural problems and intensify sociological problems of the population inhabiting these areas, including an increase the spread of waterborne diseases.

Currently, water logging in Cochin is experienced during the monsoon season. This water logging is result of drainage constriction caused by heavy development encroaching along the edges of the Cochin canals, continuing uncontrolled development reducing the amount of open lands available for absorption of water, and clogging of drains due to input of solid wastes. About 15 areas encompassing approximately 53 square kilometers in the center of the city have become increasingly subject to water logging (Figure 3).

Many of the low-lying coastal areas in Cochin are also subject to tidal influences, further reducing the draining of runoff during the rainy season. As indicated above, the central area of Cochin city is little more than one meter above mean sea level and subject to backwater tidal fluctuations, whereas the West Cochin area is subject to more direct sea tidal fluctuations.

In addition, more intense rainfall events in combination with the current problems of poor drainage and water logging within Cochin can be expected to promote more damaging flooding under the projected future conditions, and even a relatively modest degree of sea level rise could add to Cochin's flooding problems. Considering that current flood relief expenditures are considered to be high (data unavailable), an increase in flooding could become a serious budgetary concern as well as a social, economic, and environmental concern.

Potable Water

Both the ground and surface water within Cochin are saline and polluted, extensively used for many purposes but not suitable for drinking. The only source of potable water is the Periyar River, approximately 20 km east of the city. After treatment, the water is distributed by the state of Kerala. However, with the current infrastructure, the system is not able to satisfy the demand; the estimated per capita water consumption for the area is 200 liters/person, whereas the availability is less than 80 liters/person. Some of the difference is made up by withdrawals of water from the aquifer for purposes other than drinking, but a scarcity of potable water is one of the most urgent and visible sources of political discontent in the city. Some state-level projects are planned or partially completed, aimed at supplying a part of the additional water needed, and the city is looking into possible roles in this regard as well.

Changes in rainfall patterns described in Section 3 could add to the magnitude of this challenge. Increased rainfall intensity can affect the quality of the drinking water supply by increasing erosion and the sediment load of the river. It can also increase flooding, resulting in the release of additional pollution into the supply and reducing the proportion of precipitation that is captured for productive use. Increased variability in rainfall amounts may affect availability of sufficient supplies, especially during the dry seasons in relatively dry years. In this case, the current gap between supply and demand for potable water could increase unless water supply infrastructures are improved.

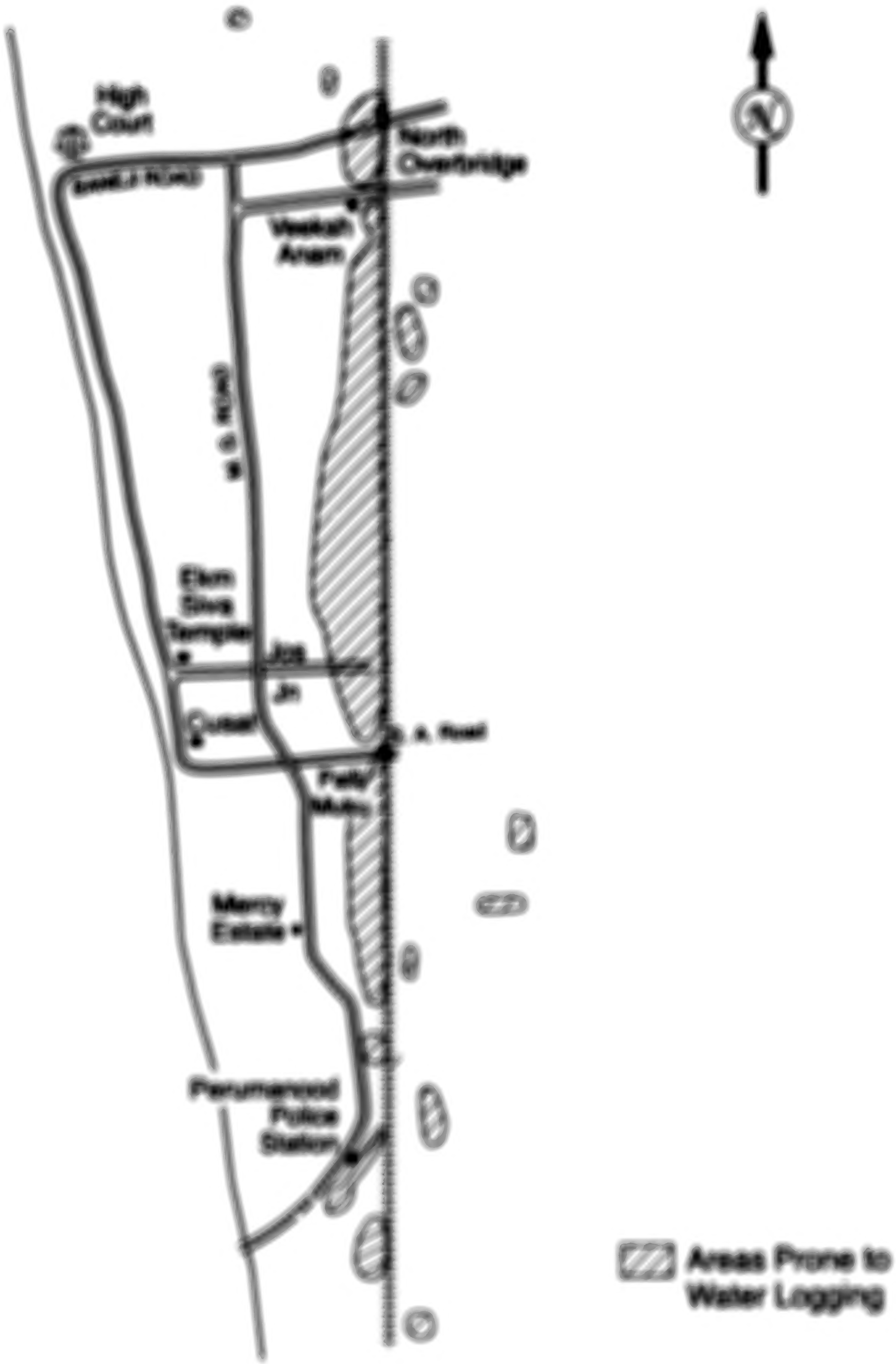


Figure 3. Areas prone to water logging in Ernakulam (after Eelsam, 2002).

Coastal Area Impacts

Impacts within the Cochin Corporation

The principal expected impacts of climate change on the coastal portions of the Cochin Corporation are sea level rise, accompanied by increased erosion of shorelines in some areas, and an increased incidence of water logging and flooding. Because most developed areas along the shoreline are no more than 1 meter above sea level, even a modest rise in sea level (0.3 to 0.5 meter) could bring some developed coastal areas under threat of inundation at high tide or during monsoonal storms. Additionally, saltwater intrusion into ground and surface waters would be expected to advance farther inland. If this were to result in population relocations, the resulting additional congestion in the higher portions of the central Corporation area would increase stresses on the existing infrastructure.

Beach erosion is another concern, because it is already occurring on the sea margins of Fort Cochin/Mattancherry. The beaches along Kerala's coast, especially in the Cochin area, are of a barrier type backed by the seasonal occurrence of mud banks. Historically, erosion and accretion along the coast operated on a cyclical basis. However, in more recent times erosion has played the major role. During the early nineties, along the Fort Cochin beaches (south of the Cochin Harbor entrance) the beaches extended about 100 meters from the benchmark before the onset of the monsoon. Today, a major portion has been eroded due to the intensity of the monsoon waves. On the other hand, Vypin Island beaches just north of the channel show an accretion effect. This may be due to the southerly littoral drift, which has been blocked by the rich outflow through the channel during monsoon resulting in a lack of sediment supply from north and led to erosion in Fort Cochin beaches. At present the stretch from Fort Cochin to Arathungal has no beachfront at all.

Forecasts of more intense precipitation events as climate change occurs would appear likely to be associated with more intense wave activity, accelerating the coastal erosion rate, with all effects magnified by sea level rise.

Impacts Elsewhere in the Metropolitan Area

While the main Corporation of Cochin area averages only 1.5 meters above mean sea level, many of the surrounding islands are even lower-lying: typically 1.2 to 2.1 meters above nominal sea level, when high tide with storm surges is +1.2 meters. Even a marginal increase in the sea level, as predicted by climate change forecasts, could make significant portions of these islands unsuitable for habitation. Moreover, the pattern of alternate paddy rice cultivation and prawn/shrimp farming which has developed on some of islands over the past ten years would in many cases be affected by inundation and salt-water intrusion associated with projected sea-level rise. On some of the islands, in fact, the population density is above the state average. If some or a considerable portion of that population were to be forced by sea-level rise to leave islands that become uninhabitable, the city of Cochin could be faced with an influx of landless poor, increasing crowding and other problems associated with urban growth and a lack of infrastructure within the area of the Cochin Corporation (see Photos 4 and 5).

The Goshree Islands Development Authority (GIDA) coordinates development in a larger coastal area extending to eight panchayaths and a portion of the Corporation of Cochin, including 27 islands, large and small. The total area of its jurisdiction is 100.8 square kilometers, with a total developed area of 53 square

Photo 4. Low-Lying Islands I: These are already very close to sea levels and are vulnerable to sea-level rise.

Photo 5. Low-Lying Islands II: Some of the islands are settled, protected from high-tide sea level by low sea-walls ("bunds").

kilometers. Total population in 1991 was 203,599; the projected population of the area is 265,015 in 2011 and 293,334 in 2021.

The centerpiece of GIDA's ambitious agenda is a locally self-financed "Three Bridge Project" that will promote sustainable development in the Cochin area by linking major islands near the mainland of the Corporation of Cochin to the mainland via three new bridges, together with the development of a modern, world-class container terminal on Mulavukad Island. The project will also include road development.

Sea level rise could be considered a threat to many of the islands under GIDA's auspices, plus the major capital infrastructure project. The project, in fact, is being designed so that sea-level rise can be accommodated: i.e., with bridges and connecting roads at a minimum level of 3.0 meters above average sea level. Possible impacts on the low-lying islands, especially smaller islands not served by the three bridges, however, are more problematic, calling for a significant response if an eventual threat of population displacement is to be reduced.

Waste Management

It is common in Cochin to distinguish between solid waste, such as garbage, and sanitary (liquid) waste. In a city without comprehensive waste disposal infrastructures for either, the stresses of waste disposal on sustainable development are severe.

Solid Waste

Solid waste management is one of the many major responsibilities of the Cochin Corporation. A lack of designated waste disposal sites and an inadequate collection and disposal system cause chronic challenges for health, sanitation, and environmental degradation. Cochin Corporation generates 330 Mt–400 Mt of solid waste per day, with per capita solid waste production of nearly 500 g. Households and small shops contribute about 67%, markets (vegetable, fruits, and meat) about 10%, hospitals and health care establishments another 10%, and hotels and restaurants the remaining 13%.

Solid wastes of both organic and inorganic nature are collected by container lorries and trillers and deposited on municipal land provided for that purpose at Willingdon Island, Cheranellur, and Brahmapuram. On the average, approximately 50-60% of the solid waste produced daily is removed by the Corporation. At the landfills, collected wastes are covered with gravel. The remaining waste is dumped into canals and drains. Streets, canals, and grounds where uncollected solid wastes accumulate are unsightly and unhygienic, emitting foul odors which attract flies and rodents, promoting the spread of communicable diseases and discouraging touristic interest in the city. This situation is an existing aspect of life in Cochin.

Possible impacts of climate change, including increased variability of rainfall patterns and more intense short-duration events during the southwest monsoon—especially in combination with a rise in the water table associated with sea level rise—would be expected to cause more serious water logging, which promotes the accumulation of wastes in canals for longer durations. This situation already contributes to disease outbreaks, and such impacts might become more frequent and severe. The combination of water stagnation, waste accumulation, and warm temperatures provide an excellent breeding ground for disease organisms and the disease vectors (mosquitoes, flies, and rodents) which can transmit the diseases to humans. The accumulation of solid wastes in water logged areas can also lead to increased leaching of pollutants from the wastes into ground water, leading to further pollution of land and water systems.

Sanitary Waste

At present, sanitary waste disposal in Cochin is limited to a small portion of the Corporation (about 20%), with only one treatment plant at Elamkulam. Many households have their own septic tanks, which are cleaned by the corporation on demand. High rise buildings, including apartments constructed in recent years, also have their own tanks. Outlets of the septic tank and washing systems are connected directly to the public drains; therefore, both perishable and non-perishable elements are being constantly introduced into the drains. During periods of water logging and flooding this is of particularly serious concern. Many residents along the sides of the canals use the city's canals as dumping sinks for sanitary waste. With the changing global climate, Cochin's existing sanitary waste conditions, in combination with saltwater intrusion, are likely to increase their contributions to the continuing degradation of local water systems.

Human Health

The city of Cochin has a government hospital and about 30 other hospitals, including primary health centers and Employees State Insurance (ESI) hospitals. Apart from the conventional hospitals, the industrial belt of Cochin houses a variety of health care centers as well: hygiene management nodal points such as the Occupational Health Hazard Centre in Indian Aluminium (INDAL), Eloor. The Amritha Institute of Medical Sciences (AIMS), a specialty hospital, operates a Department of Community Medicine to look into the health of the urban population, and a health survey is currently under-way. However, at present there is no clear documentation of health conditions in Cochin, including economic and social backgrounds of patients and covering private care as well as public care.

It is well established that global climate change could result in health impacts. Direct health impacts could result from any effects of climate change on ecological systems and could include changes in infectious disease occurrence, concentrations of local air pollutants, and exposures to allergens. Indirect impacts could include changes in agricultural patterns, changes in fish stock, and various health consequences of population displacement and economic disruptions.

Vulnerabilities to health from climate change in Cochin are most likely to be associated with two phenomena: health implications of water system challenges (e.g., water logging) and possible dangers from flooding and other effects of more intense rainfall events. As indicated above, changes in the pattern of precipitation in the region around Cochin are likely to contribute to major water logging problems and associated impacts. The economically poorest portions of the population are expected to be the most vulnerable. Infectious diseases associated with water logging and environmental pollution, including leptospirosis, typhoid, gastroenteritis and viral fever, have shown rising trends in the recent years. Leptospira infection results from exposure to alkaline water, damp soil or vegetation contaminated with the urine of infected wild and domestic animals. Common among sewage and farm workers, this disease is concentrated in and around the old Cochin area. Outbreaks occur after heavy rainfalls and during floods (e.g., hepatitis A and leptospyrosis show higher incidence during the monsoon period), and increased flooding associated with climate change would be expected to affect the incidence of such diseases.

Gastroenteritis, a water-borne disease, is very common in the city. Water contamination, together with a scarcity of pure drinking water, is a major factor in the spread of this disease. If a greater variability in patterns of rainfall leads to occasional decreases in potable water supplies, while stresses on the city's water systems lead to an increased concentration of pathogenic organisms in raw water supplies, this disease could increase as a problem.

Stagnant waste water in drains acts as a breeding ground for mosquitoes. Cases of filariasis, Japanese encephalitis, etc., have been reported in the city. Measures taken to control the mosquito problem through applications of chemicals in the form of burning coils and vaporizing liquids have been found to be affecting the health of the urban population.

Weather conditions influence air pollution via pollutant transport and formation. Exposure to air pollutants can have very serious health impacts especially following severe pollution episodes. There is evidence of a [illegible]–70% increase in respiratory diseases in certain parts of the Cochin metropolitan area in recent years. Skin diseases and allergy disorders are also found to be increasing, especially over and down-wind from the industrial belt of Eloor. Lower income groups are more vulnerable because of their general health conditions and smoking habits.

Hydropower and Energy

Energy generation and distribution are under the management of the State of Kerala rather than the Corporation of Cochin. Nevertheless, it is worth examining the potential impact of global warming on the power sector, because of possible effects on electricity availability and cost. In Kerala, until 1996 almost 100% of the electric power was generated from hydroelectric projects, which are the least expensive resource/technology alternative. Due to continued development in and around Cochin, the demand for power has been growing exponentially, with demand exceeding production, and the city began experiencing power shortages. During the period 1996 to 2000, thermal power projects were added in Kerala, increasing capacity by 873 MW. Today, total power generation in Kerala is about 2600 MW, which almost meets the present demand. But the share of hydroelectric power decreased from 100% in 1976 to 53% in 2002, and electricity production costs have risen steadily (more rapidly than electricity prices, which threatens the economic viability of the state utility). Even now, Kerala has potentials for additional hydroelectric power, but because of concerns about environmental impacts no major projects have been added since 1976. The present government is rethinking its policies toward small environmentally friendly hydropower projects, and projects totaling about 300 MW are in progress.

Since Kerala's electricity costs are affected by the share of power produced from hydroelectric facilities, and the state has further potentials for hydroelectric power generation, global warming and related changes in the local climate could have important implications for the power sector. Obviously, hydroelectric power generation depends basically on the total rainfall received. Any decrease in rainfall can seriously affect the generation potential, and increased annual variability could make hydropower supply less reliable. Secondly, a temperature increase would widen the gap between supply and demand because of the increased demand for power for air conditioning and refrigeration in the working and living environments.

Tourism and Cultural Heritage

Tourism is driven by a desire for pleasurable and unique experiences. Increased population density, increased environmental pollution and water logging of portions of the city, increased risks of disease and other threats to human health, threats to the canal system's viability, threats to the nearby backwaters, and a possible loss of cultural resources (due to inundation and other factors) run counter to a desire to maintain and enhance Cochin's attractiveness to tourists.

Cochin City has a great heritage and a timeless tradition. Its many centuries of trade and cultural contacts with the rest of the world, along with its diverse colonial experience, have added to the structures and artifacts rooted in Kerala's own cultural history a unique range of architecture and historic sites. In addition, the backwater area is a world-class tourist attraction, and the water-based landscape of the harbor and port areas make Cochin a very special experience.

Cochin's urban heritage was until recently environmentally friendly. Monuments and cultural environments, however, are non-renewable resources; and their management must be based on long-term perspective in order to be conserved as the area's cultural heritage. It is this realization that led Cochin Corporation to establish a Center for Studies in Culture and Heritage of Cochin (CSCHC), committed to protect and preserve the cultural heritage of Cochin. The primary objective of the center is to develop, apply, and make available appropriate information and advice for the preservation of cultural heritage of Cochin through research, training, and fieldwork and information exchanges. Among its interests is restoring Cochin's canal system to a clean, attractive, multiple use asset for the city.

Since many of the historic structures of Cochin are located in low-lying areas, any sea-level rise related to global warming could have a direct impact on cultural heritage protection. In addition, the degradation of historic structures would be accelerated by increased temperatures and precipitation (and possibly by poor surface drainage and water logging), proposed beach developments would be threatened by beach erosion, and canal restoration could be challenged by rainfall changes and sea level rise.

Fisheries

Significant changes in temperature and precipitation may result in changes in the growth and range of habitation of flora and fauna species. For instance, native species may be replaced by non-native species that are less sensitive to climate changes or are better adapted to the changed conditions. Clearly, temperature and sea level increases, precipitation changes, and the associated changes in water chemistry can significantly affect the population dynamics of aquatic and marine species; and shifts in habitat availability and migration patterns can significantly affect commercial and sport fishery productivity.

Fisheries are a very important sector of the Kerala economy in general and Cochin's economy in particular. Fish and fishery products account for one-fourth of total export earnings in Kerala. Marine fish production in Kerala shows an increasing trend from 1950, but the average rate of growth in Kerala appears to be lower than the all-India average. Half a century ago, Kerala accounted for nearly 40% of India's commercial fishing, but its share has declined since the mid-1960's, and Kerala no longer dominates marine fish production in the country. The fish catch, in fact, has been almost stagnant since 1991. Recent trends show a steady decrease in the percentage contribution of pelagic (shallower water rather than deep-sea) fishes, mainly because of improvements in vessels for deep-sea fishing.

Fish populations are generally very sensitive to changes in the sea surface temperature, which can have an especially significant impact on the behavior and reproduction of pelagic fishes such as pomfret, tuna, mackerel, perch, and sardines. Seawater off the Cochin coast has shown a slow but steady increase in its temperature since the 1930s, with abnormally high temperatures at the surface during the southwest monsoon season; and studies of this trend are being conducted by the Department of Science and Technology of the Government of India. A study of effects of this temperature increase on fish populations has not been conducted, but there is a possibility that an increase in sea surface temperature—experienced

or projected—would have an impact on the production and migration of fish populations, especially pelagic fishes, which in turn would affect the economy of this area.

One issue, for instance, is possible changes in fish diseases associated with sea temperature changes. In addition, the temperature of the water affects the activity, behavior, growth, and reproduction of most species, including metabolic rates and resistance to diseases, as well as ecological niches for different species in relation to each other. A number of diseases affecting marine prawns are associated with periods of the year when both water and air temperatures are high and such associations are likely to be reflected in impacts on fishing of climate change.

CLIMATE CHANGE IN OTHER REGIONS

Climate changes on a global scale may be expected to bring about substantial changes in growing season and agricultural practices in many regions of India and the world. On a regional basis, these changes could be extensive, depending for example on the frequency and quantity of rainfall. On the Indian subcontinent, parts of the interior are expected to receive reduced rainfall, while some coastal areas are expected to experience more intense monsoon rains over shorter periods of time. Such changes may impact traditional commercial practices by affecting the availability of foods and other agricultural products. As Cochin relies largely on import of such materials from surrounding regions, it may be anticipated that the availability of traditional foods, textiles, and rubber products could be affected.

If they were to occur, increased drought events in the interior of India might also result in increased migration of populations currently inhabiting these areas toward the coast. Cochin would most likely be viewed as a prime migration destination. Such a sequence of events would place increasing stress on the on the already over loaded infrastructure of Cochin, including solid and liquid waste management, canal and drainage problems, and potable water.

In addition, Cochin's economy depends on its competitiveness in a number of global markets. Climate changes in other regions that are Cochin's competitors or markets could affect its economy in either negative or positive ways.

CONCLUSIONS: VULNERABILITIES OF COCHIN TO IMPACTS OF CLIMATE CHANGE

The findings of this assessment indicate that climate change alone is not necessarily a major threat to Cochin, depending on how the city responds. It is one of many factors in considering future development paths for the city and metropolitan area, and its main significance is in adding to stresses that already exist. On the other hand, some of these added pressures could become problematic for the city in the longer run unless steps are taken to increase the city's resilience in these regards. This section identifies the two most significant impact concerns for Cochin, several other possibly significant concerns that deserve further attention, and a number of additional concerns that may call for attention in the long run, depending on the area's emerging experience with climate change and its impacts. In all cases, adaptive responses by Cochin, in collaboration with a variety of partners, can improve the area's resilience and, in important ways, demonstrate leadership in climate change-related responses among cities in Kerala, India, and the developing world.

SIGNIFICANT IMPACT CONCERNS

The Cochin area's most significant vulnerabilities to climate change impacts in the long run are:

(1) *Possible impacts of a combination of (a) increased variability and intensity of rainfall and (b) sea level rise on Cochin's water systems*, especially on drainage, waste disposal, and waterlogging. Unless action is taken to increase the effectiveness of Cochin's water and waste disposal systems, especially its canal network, climate change is likely to significantly increase the city's problems with environmental pollution, waterlogging, and flooding. This, in turn, has the potential to undermine the area's attractiveness as a healthy place to live, a pleasant place to do business, and a desirable place for tourists to visit. It appears that such *adaptation* actions, which offer substantial co-benefits for the city's sustainable development, can significantly reduce vulnerabilities of the water systems to long-term climate changes.

(2) *Possible impacts of sea level rise on* land uses *at the coastal margin*. Unless action is taken to respond to the likelihood that sea level rise may threaten land uses at or near the shore line, climate change is likely to threaten some coastal land uses and patterns of livelihood. The challenge appears to be especially significant for some low-lying backwater islands under the jurisdiction of the Goshree Islands Authority, where even a modest sea level rise—with associated flooding, waterlogging, and water salination—could threaten current ways of life. If some of the currently inhabited islands were to become uninhabitable, the displaced population would be expected to move to other parts of the Cochin area, possibly without homes or jobs, which would present a different kind of urban management problem. This impact concern can be reduced through certain possible *adaptation* actions (see box), but only *if* the sea-level rise is moderate rather than massive. In other words, in this impact connection, climate change *mitigation* actions at a global scale are an essential part of an effective response, along with selected adaptation actions.

POSSIBLY SIGNIFICANT IMPACT CONCERNS

Several other types of climate change impacts could also be significant for Cochin, although currently available information is insufficient to support an assessment of the appropriate level of concern. These concerns, which call for further investigation, are:

(1) Possible impacts of climate change on human health. If temperatures increase, precipitation patterns change, and/or such secondary effects as increased water logging or waste disposal problems emerge, it is possible that the Cochin area could be exposed to more or different pests, disease vectors, and diseases. If this danger is significant, actions to strengthen the city's public health systems would be desirable.

(2) Possible impacts of climate change on the Cochin area's fisheries industry. If seawater in the Cochin area warms with global climate change, it is possible that fish populations in the shallower waters could be adversely affected and that this sector of the area's economy would be impacted. If this danger is significant, as in the case of the Godavari Islands, both global climate change mitigation and local adaptations (from changing fishing patterns to fish species development) would be desirable.

(3) Possible impacts on Cochin's cultural heritage. Any or all of the increased stresses that may be associated with climate change could have undesirable impacts on cultural heritage preservation, from accelerated deterioration of historic structures to accelerated loss of historic landscapes, including aspects of the backwater areas, to reduced touristic interest due to inadequate waste disposal systems. Combined with other types of economic, environmental, and technological change over the coming decades, climate change could add to the substantial challenges of realizing Cochin's visions as a special cultural heritage area. If this danger is significant, actions already begun thr.ugh the Corporation of Cochin's Centre for Studies in Culture and Heritage of Cochin (CSCHC) should be pursued vigorously to couple other climate change related actions to historic preservation, such as canal restoration.

(4) Possible impacts on Cochin from climate changes in other regions. It would be desirable for Cochin to become better informed about possible effects on its society and economy from climate changes elsewhere, from the agricultural areas inland in Kerala whose production might be impacted by changes in precipitation patterns to the potential for in-migration by environmental refugees from

drought-stricken interior regions. This possible danger calls for long-term contingency planning based on improved sources of information.

Other Impact Concerns

A host of additional possible impacts might be of concern in the Cochin area and should at least be included in enhancing public awareness of climate change and associated impact issues for the area. One example is increased variability in hydropower production and associated variabilities and possible increases in electricity costs for Cochin metropolitan governments and their citizens.

34

BLANK PAGE

RECOMMENDATIONS FOR ACTION

Because climate change is a long-term concern surrounded by uncertainties, it is not appropriate for Cochin to undertake adaptive actions whose only benefit is to increase resilience to climate change. The challenge is to identify actions that (a) will increase resilience but at the same time (b) help to address current stresses on Cochin's urban management that are likely to be exacerbated by climate change and (c) represent a sound investment in sustainable development: win-win-win propositions. Actually, climate change is an opportunity for Cochin rather than a problem, for at least two reasons. First, the high level of concern among the global community about climate change impacts on developing countries offers sources of technical and financial assistance for urban projects that would not otherwise be available, as long as those projects can be linked to climate change issues. Second, the fact that this assessment is the first of its kind in any developing country city puts Cochin in a position of potential leadership, both regionally and globally. Already, it appears that the Goshree Islands project has been designed so that the three new bridges, the port facility, and the associated roads would not be threatened by a projected sea level rise, which makes it a pace-setter in adaptive actions in developing countries.

Actions recommended for Cochin as responses to climate change concerns can be defined on a number of different levels. For instance, one consideration is what Cochin should do in terms of comprehensive strategies for near-term stress reduction and longer-term sustainable management and financing. Another consideration is what Cochin should do in partnership with various other specific organizations such as USAID.

Recommended actions for Cochin, if support were to be available from appropriate sources, include developing comprehensive plans for waste disposal (both solid and sanitary), canal restoration, cultural heritage protection and tourism, and other possible sources of stress on (and opportunities for) the city's environmental, economic, and social systems. These plans would include assessments of technology availability, sustainable institutional and financial management, and "road maps" toward resources for implementation. More specifically, in order to reduce its vulnerabilities to climate change impact while at the same time reducing stresses on current sustainable development, the assessment suggests that Cochin and its partners in the Cochin area should:

- Identify and implement effective waste disposal infrastructures and policies for both solid and sanitary wastes.
- Restore the city's canal system to a level where major canals are clean and suitable for multiple uses and other canals are effective in assuring drainage of the metropolitan area.
- Stabilize the coastal margin of the city so that erosion does not threaten land uses and historical, cultural, and aesthetic assets.
- Explore, test, and demonstrate approaches for protecting low-lying coastal islands from sea-level rise.
- Take steps to improve the efficiency of energy use, especially in governmental functions, in order to reduce impacts of possible future energy price increases and to make more electricity available to other consumers in the metropolitan area.
- Build upon the city's experience with this assessment to become a recognized leader, nationally and internationally, in understanding relationships between climate change and urban sustainable development.

In line with these general recommendations for Cochin, the assessment recommends a number of specific first steps toward a more comprehensive response, several related to activities already under way. These steps, we suggest, are likely to lead to further steps that would add up to a truly historic program of action for the Cochin area.

The recommended actions are as follows:

(1) Take steps to address Cochin's inadequate waste disposal infrastructure. It is recommended that, in collaboration with USAID, Cochin upgrade its plans for solid waste disposal. To assist in this effort, USAID has supplied technical assistance to help Cochin meet Indian Supreme Court requirements for solid waste disposal planning.

(2) Identify funding sources and develop a proposal for funding of a canal restoration initiative. It is recommended that Cochin explore funding potentials for a major canal restoration effort that might begin with a formal proposal for donor assistance for a prototype project. USAID will be assisting Cochin in scoping such a project.

(3) Take steps to link urban problem-solving with climate change mitigation as well as adaptation. As a contribution to the global effort to reduce the magnitude of climate change (e.g., the rate of sea-level rise affecting the Goshree Islands) and as a first step in linking Cochin with other developing country cities concerned about climate change issues, it is recommended that Cochin join the Cities for Climate Protection program funded and supported by USAID and administered by the International Council for Local Environmental Initiatives (ICLEI), a Toronto-based NGO, to implement a program of cost-saving energy efficiency improvements, probably emphasizing municipal facilities, vehicle fleets, and street lighting. ICLEI, in collaboration with USAID, would provide staff assistance to assemble the necessary data bases and link them with Internet-accessible software for analyzing alternatives for action. Besides the valuable international networking with other climate change concerned cities, resulting efficiency improvements would reduce impacts on Cochin city government of possible electricity price increases due to less reliable hydropower supply.

(4) Enhance Cochin's leadership position in environmentally sustainable urban management. It is recommended that Cochin provide leadership in the formation of a proposed Kerala State Council of Mayors and Kerala State City Manager's Association. And that Cochin be invited to participate in national, regional, and global conferences and forums related to urban management and also issues associated with climate change. It is also recommended that Cochin use its participation in the ICLEI network of cities to communicate its experiences and accomplishments and add to the momentum of bottom-up efforts to promote progress with climate change mitigation.

(5) Continue with efforts to strengthen linkages between the Corporation of Cochin and CUSAT for technical assistance in increasing the resilience of the Cochin area to climate change impacts and contributing in other ways to effective urban management and problem-solving and for local capacity-building. As a consequence of the assessment, CUSAT and ORNL are developing a Memorandum of Understanding for continuing technical collaboration, including such subject areas as climate change modeling and monitoring.

(6) Develop and implement an action plan to improve information to inform decision-making and project development, emphasizing certain high-priority needs and certain types of impact concerns that could emerge as significant as they come to be understood better.

High-priority needs include:

- Improved data on drainage problems, including flooding and water logging
- Improved data on climate variation and change at a relatively detailed scale in the Cochin area in order to clarify impact issues, to track changes over the coming decades, and to provide early warning about any changes that might cause specific problems for the area

Other impact concerns that need monitoring programs include:

- Impacts of climate change on the city's cultural heritage and tourism potentials
- Health trends associated with local ecological changes
- Trends in coastal land subsidence
- Trends in coastal beach/land erosion
- Trends in fish species composition and diversity and fishing production
- Possible impacts on Cochin of climate changes in other areas

38

References

Clark, W. C., et al., 2000. "Assessing Vulnerability to Global Environmental Risks," Discussion Paper 2000-12, Environment and Natural Resources Program, Kennedy School of Government. Cambridge: Harvard University.

CONAMA, 2000. *Evaluacion Ambiental de Opciones de Manejo para el Parque Nacional Rio Dulce*, Fundación Solar and Oak Ridge National Laboratory. M00-107660. Guatemala: Comision Nacional de Medio Ambiente and Consejo Nacional de Areas Protegidas, June 2000.

CUSAT, work in progress. Centre for Monsoon Studies, Department of Atmospheric Sciences, Cochin University of Science and Technology.

Dinesh Kumar, P. K., 2001. "Monthly Mean Sea Level Variations at Cochin," *International Journal of Ecology and Environmental Sciences*, 27: 209–214.

Ensminger, J. T., 2003. *Assessing Impacts of Climate Change on Coastal Areas: A Summary of the Knowledge Base*. ORNL/TM-2003/83. Oak Ridge, TN: Oak Ridge National Laboratory.

Estuarn, 2002. *Canal and Drainage Assessment for Cochin, India*. Cochin: Estuarn Developers.

Hadley Centre, 2000. "Regional Climate Simulations," Bracknell, UK: UK Met Office.

IPCC, 2001a. *Climate Change 2001: The Scientific Basis*. Cambridge: Cambridge University Press.

IPCC, 2001b. *Climate Change 2001: Impacts, Adaptation, and Vulnerability*. Cambridge: Cambridge University Press.

Lal, M., 2002. *Global Climate Change: India's Monsoon and Its Variability*. Stratus Consulting, Inc., for the U.S. Environmental Protection Agency.

OTA, 1993. *Preparing for an Uncertain Climate*. Washington, D.C.: Office of Technology Assessment, United States Congress.

Wilbanks, T., D. Hunsaker, C. Petrich, and S. Wright, 1993. "Potentials to Transfer the U.S. NEPA Experience to Developing Countries," in J. Cannon and S. Hildebrand, eds. *Environmental Analysis: The NEPA Experience*, Boca Raton: CRC Press: 728-742.

BLANK PAGE

APPENDIX A: PARTICIPANTS IN THE STUDY

CO-AUTHORS

Dr. G. Bindu, Department of Atmospheric Sciences, Cochin University of Science and Technology, Cochin, India

Sri B. Chakrapani, Department of Atmospheric Sciences, Cochin University of Science and Technology, Cochin, India

Mr. J. T. Ensminger, Senior Staff Member, Environmental Impacts Group, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA

Prof. C. K. Rajan, Director, Centre for Monsoon Studies, Department of Atmospheric Sciences, Cochin University of Science and Technology, Cochin, India

Dr. A. Simon, Department of Atmospheric Sciences, Cochin University of Science and Technology, Cochin, India

Mr. Suresh Natarajan, Department of Atmospheric Sciences, Cochin University of Science and Technology, Cochin, India

Dr. T. J. Wilbanks, Leader, Global Change and Developing Country Programs, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA

USAID PROJECT SUPPORT

Mr. R. MacLeod, Urban Program, Office of Energy and Information Technology, Bureau for Economic Growth, Agriculture, and Trade, USAID

Mr. N. B. Bhattacharjee, Urban Program, USAID/Delhi

Mr. A. Rudra, Urban Program, USAID/Delhi

ORNL PROJECT SUPPORT

Ms. Sherry B. Wright, Coordinator of Global Change and Developing Country Programs, Oak Ridge National Laboratory, Oak Ridge Tennessee, USA

Ms. Amy Campbell, Subcontract Administrator, Procurement Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA

Mr. Robert Conrad, Supervisor of Communications, Central Research Library

CORPORATION OF COCHIN PROJECT SUPPORT

Mr. K. J. Sohan, Former Mayor of Cochin; Chairman, Standing Committee, Corporation of Cochin; President, Mattancherry Cooperative Bank Ltd.

Simon Mathews, Senior Liaison Officer, Goshree Islands Development Authority

Dr. Rajan Chedambath, Secretary, Centre for Studies in Culture and Heritage of Cochin (Corporation of Cochin)

Mr. Abraham Joseph, City Engineer, Corporation of Cochin

Addressees for Review of Draft Assessment Report

20 copies to the Corporation of Cochin

Mr. K. J. Sohan, Corporation of Cochin

Central Marine Fisheries Institute: Dr. Mohan Joseph Modayil, Director; Dr. M. Rajagopalan, Head, FEM Division; Dr. N. G. K. Pillai, Head, Pelagic Division; Dr. Jayaprakash, Principal Scientist, Pelagic Division

Goshree Islands Development Authority: Mr. Simon Mathew, Senior Liaison Officer; Ms. Jaya M. S., Town Planner

National Institute for Oceanography, Cochin Regional Centre: Dr. K. K. C. Nair, Head

Achutha Menon Centre for Health Sciences, Trivandrum: Dr. K. P. Thankappan, Addl. Director; Dr. K. Mohandas, Director, Sree Chithira Thirunal Institute for Medical Sciences

KSIDC: T. P. Thomaskutty, DGM

Greater Cochin Development Authority: Elizabeth Phillip, Chief Town Planner

KWA: Dr. T. V. Jacob

Medical Trust Hospital, Cochin: Dr. Sunil K. Mathai

Confederation of Indian Industries, Cochin: Mr. Anand

Centre for Development Studies, Trivandrum: Prof. Chandan Mukherjee, Director

Center for Earth System Studies, Trivandrum: Dr. M. Baba, Director

Centre for Environmental Development, Trivandrum: Dr. Babu Ambat, Director; Dr. K. N. Subramanian, Rtd. Director

Coir Board, Cochin: Sri. Christi Fernandes, IAS

Coconut Development Board, Cochin: Chief Development Officer

KFRI, Thrissur: Dr. J. K. Sharma, Director

Spices Board, Palarivattom: Chairman

Cochin Port Trust: Dr. Jacob Thomas, IAS

Thrippunithura Municipality: N. K. Pavithran, Chairman

Kalmassery Municipality: K. K. Mohanan, Chairman

CIFT, Cochin: Director

CUSAT: Dr. N. Unnikrishnan Nair, Vice Chancellor; Dr. S. Anilkkumar, Public Relations Officer

Dr. K. K. George, Cochin

Attendees at the Expert Workshop, February 4, 2003

Ms. Mary P. Mathews, Senior Town Planner, GCDA

Ms. Elizabeth Philip, Chief Planner, GCDA

Ms. M. S. Jaya, Town Planner, GIDA

Mr. Simon Mathews, Senior Liaison Officer, GIDA

Dr. P. V. S. S. K. Vinayar, Scientist-in-Charge, Centre for Earth Science Studies, Cochin

Dr. V. N. Sivasankar Pillai, Director, School of Environmental Studies, CUSAT

Dr. T. V. Jacob, Cochin

Dr. R. Damodaran, Vytilla, Cochin

Dr. P. Serathan, Department of Marine Geology and Geophysics, CUSAT

Dr. Joshy, Chief Surveyor, Cochin Port Trust

END

10-21-03